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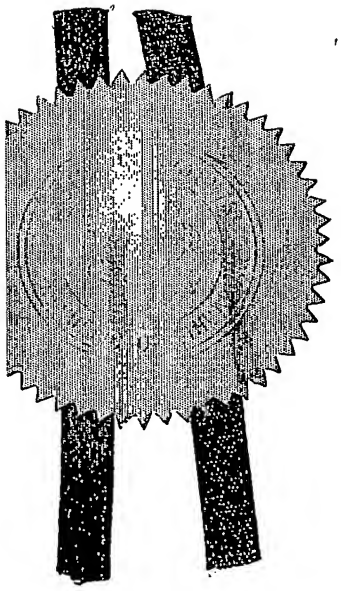
Date of Filing	:	09 SEP 2002
Application number	:	200205422-9
Applicants	:	HYDROBALL TECHNICS PTE LTD
Title of Invention	:	A CLEANING SYSTEM

I further certify that the annexed documents are not, as yet, open to public inspection.

PRIORITY DOCUMENT
SUBMITTED OR TRANSMITTED IN COMPLIANCE WITH RULE 17.1(a) OR (b)



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10 Apr 2003

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PATENTS FORM 1
Patents Act
(Cap. 221)
Patents Rules
Rule 19

INTELLECTUAL PROPERTY OFFICE OF SINGAPORE

REQUEST FOR THE GRANT OF A PATENT UNDER SECTION 25

101101

* denotes mandatory fields

1. YOUR REFERENCE* HBT02001

200205422-9

2. TITLE OF INVENTION* A CLEANING SYSTEM

3. DETAILS OF APPLICANT(S)* (see note 3) Number of applicant(s) 1

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[X] For corporate applicant [ ] For individual applicant

State of incorporation: SG State of residency:

Country of incorporation: SG Country of residency:

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(B) Name:

Address:

State: Country:

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200205422-9

ACTION

☐ For corporate applicant ☐ For individual applicant

State of incorporation | State of residency

Country of incorporation | Country of residency

☐ For others (please specify in the box provided below)

(C) Name

Address

State | Country

☐ For corporate applicant ☐ For individual applicant

State of incorporation | State of residency

Country of incorporation | Country of residency

☐ For others (please specify in the box provided below)

☐ Further applicants are to be indicated on continuation sheet 1

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4. DECLARATION OF PRIORITY (see note 5)

A. Country/country designated

File number | Filing Date DD MM YYYY

B. Country/country designated

File number | Filing Date DD MM YYYY

☐ Further details are to be indicated on continuation sheet 6

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5. INVENTOR(S)* (see note 6)

A. The applicant(s) is/are the sole/joint inventor(s) Yes ☐ No ☒

B. A statement on Patents Form 8 is/will be furnished Yes [X] No [ ]

6. CLAIMING AN EARLIER FILING DATE UNDER (see note 7)

[ ] section 20(3) [ ] section 26(6) [ ] section 47(4)

Patent application number [ ]

DD MM YYYY

Filing Date [ ]

Please mark with a cross in the relevant checkbox provided below
(Note: Only one checkbox may be crossed.)

[ ] Proceedings under rule 27(1)(a)

DD MM YYYY

Date on which the earlier application was amended [ ]

[ ] Proceedings under rule 27(1)(b)

7. SECTION 14(4)(C) REQUIREMENTS (see note 8)

Invention has been displayed at an international exhibition. Yes [ ] No [X]

8. SECTION 114 REQUIREMENTS (see note 9)

The invention relates to and/or used a micro-organism deposited for the purposes of disclosure in accordance with section 114 with a depository authority under the Budapest Treaty.

Yes [ ] No [X]

9. CHECKLIST*

(A) The application consists of the following number of sheets

i.	Request	8	Sheets
ii.	Description	14	Sheets
iii.	Claim(s)	5	Sheets
iv.	Drawing(s)	6	Sheets
v.	Abstract (Note: The figure of the drawing, if any, should accompany the abstract)	1	Sheets
Total number of sheets		34	Sheets

(B) The application as filed is accompanied by:

[ ] Priority document(s) [ ] Translation of priority document(s)

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[X] Statement of inventorship & right to grant

[ ] International exhibition certificate

10. DETAILS OF AGENT (see notes 10, 11 and 12)

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Firm

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Building Name ROCHOR CENTRE

Postal Code 180001

12. NAME, SIGNATURE AND DECLARATION (WHERE APPROPRIATE) OF APPLICANT OR AGENT* (see note 12)
(Note: Please cross the box below where appropriate.)

[X] I, the undersigned, do hereby declare that I have been duly authorised to act as representative, for the purposes of this application, on behalf of the applicant(s) named in paragraph 3 herein.

SOH BENG KIAT, PETER
Name and Signature

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09 SEP 2002

A Cleaning System

Background and Field of the Invention

This invention relates to a cleaning system which uses mobile cleaning elements for cleaning the inside of tubing.

A heat distributing system typically has a condenser unit which includes tubing to conduct fluids. There have been proposed different ways of cleaning the inside of such tubing to prevent the build up of dirt or other unwanted deposits inside the tubing as the fluids travel through the tubing.

One proposed way is the use of cleaning balls made of rubber or spongy material which have a diameter slightly larger than the tubing so that when they travel through the tubing with the fluid, the balls are compressed. In this way, the balls are made to rub against the walls of the tubing so as to keep the walls clean and substantially free from deposits. Generally, the balls and the fluid are passed through the tubing, in the direction of the fluid flow, from the upstream side to the downstream side of the tubing. The balls are then separated from the fluid at the downstream side and then recirculated back to the upstream side of the tubing. A pump, such as that described in patent document US6,070,652, typically provides the means to recirculate the balls. However, a disadvantage of using a

pump to recirculate the balls is that the pump is susceptible to malfunctioning and such a system usually requires considerable downtime for maintenance and repair.

To overcome the above disadvantage, there has been proposed a cleaning system that does not use a pump to recirculate the balls, an example of which is described in patent document US 5,592,990. In this prior art, the recirculating means comprises a housing disposed between the upstream and downstream side of the tubing. The housing includes an apertured partition which divides the housing into an upper compartment and a lower compartment. When the balls are recirculated and collected by this housing, the partition permits the fluid to pass through to the lower compartment while keeping the balls in the upper compartment. The housing further comprises a first passageway which connects one end of the upper compartment to the downstream side of the tubing, a second and third passageway connecting the other end of the upper compartment to a first and second section in the upstream side of the tubing such that the second section of the tubing has a slightly lower pressure compared to the pressure at the first section but higher than that at the downstream side of the tubing. The housing also comprises a fourth passageway connecting the lower compartment to a source of lower pressure than that in any of three other passageways. The cleaning system disclosed in this prior art also has a plurality of valves arranged to control the fluid flow along the different passageways

described above. A disadvantage of this prior art is the complexity of the design which requires a sequence of actions to close and open the plurality of valves to recirculate the balls. In addition, to draw the balls into the housing, the valve disposed at the fourth passageway must be opened and this may discharge the fluid. As a result, the fluid is wasted each time the balls are recirculated and the cost of maintaining such a system may be relatively expensive.

It is an object of this invention to provide a cleaning system which alleviates at least one of the disadvantages of the prior art.

Summary of the invention

The invention, in general terms, is to provide a system for cleaning tubing connected to an inlet pipe and an outlet pipe, using cleaning elements, such as balls, which are recirculated by controlling two valves.

According to a first aspect of the present invention, there is provided a cleaning system for cleaning tubing used for conducting a fluid therethrough, the tubing being connected to an inlet pipe and an outlet pipe, the system comprising

a plurality of cleaning elements for circulating with the fluid through the tubing;

a separator disposed at the outlet pipe and arranged to separate the cleaning elements from the fluid;

recirculating means arranged to selectively transfer the plurality of cleaning elements from the outlet pipe to the inlet pipe, wherein the recirculating means comprises

a housing arranged to collect the cleaning elements;

a ball supply pipe having an entrance coupled to the housing and an exit coupled to the inlet pipe;

a fluid supply pipe having an entrance coupled to the inlet pipe and an exit coupled to the housing;

the entrance open mouth of the fluid supply pipe is formed in the direction against the fluid flow of inlet pipe such that the pressure at the entrance of the fluid supply pipe is higher than that at the exit of the ball supply pipe;

a fluid return pipe having an entrance coupled to the housing and an exit coupled to the outlet pipe;

a ball return pipe having an entrance coupled to the separator and an exit coupled to the housing; and

the entrance open mouth of the ball return pipe is formed in the direction against the fluid flow of outlet pipe such that the pressure at the entrance of the ball return pipe is higher than that at the exit of the fluid return pipe.

An advantage of the described embodiment of the invention is that the different pressures at the inlet pipe and the outlet pipe create suction force which provides an easy and cost efficient way of circulating the cleaning elements for cleaning

the tubing. Such a system is also environmental friendly since there is no wastage of the fluid.

The invention is particularly useful for cleaning the fluid-conducting tubing of a heat-exchanger or a condenser, and the invention is therefore described below with respect to such an application.

Brief Description of the Drawings

An embodiment of the invention will now be described, by way of example, with reference to the accompanying drawings, in which: -

Figure 1 illustrates a cleaning system according to the invention which comprises a housing to collect the balls at rest and a separator;

Figure 2 illustrates the cleaning system of Figure 1 when the cleaning balls are caused to circulate through the tubing;

Figure 3 illustrates the situation when the balls have passed through the tubing and are trapped by the separator of Figure 1;

Figure 4 illustrates the situation when the balls are caused to circulate back to the housing of Figure 1;

Figure 5 illustrates a cross-sectional view of the separator of Figure 3 which traps the cleaning balls after they have passed through the tubing; and

Figure 6 shows a detailed view of the separator of Figure 5.

Detailed Description of the Preferred Embodiment

Figure 1 illustrates a cleaning system used to clean tubing 8 in a condenser 7. The tubing 8 is in the form of a plurality of parallel spaced tubes which are connected to an inlet pipe 5 and an outlet pipe 9. A cooling fluid such as water is passed through the tubing 8 in order to condense another fluid, such as steam or a refrigerant gas, from an inlet 25 which circulates through the spaces between the tubing 8 and to an outlet 29.

The cooling fluid (in a direction as indicated by W1) is circulated through the condenser tubing 8 from an inlet duct 1, which is connected to the upstream side of the condenser tubing 8 by the inlet pipe 5, to an outlet duct 15 connected to the downstream side of the tubing 8 by the outlet pipe 9.

The cleaning system comprises a plurality of cleaning elements and in this embodiment cleaning balls 20 are used. Such cleaning balls 20 are typically made from spongy material and have a diameter slightly larger than the diameter of the tubing 8 so that the balls 20 are compressed when they are forced through the tubing 8 to prevent the lodging or settling of particles within the tubing 8. In this way, unwanted deposits are prevented from building up in the tubing 8 which

may lower the efficiency of the heat exchange, or even cause corrosion.

The cleaning system further comprises a separator 12 and recirculating means to transfer the cleaning balls 20 from the outlet pipe 9 to the inlet pipe 5.

The function of the separator 12 is to separate the cleaning balls 20 from the cooling fluid at the outlet pipe 9 and in this embodiment, the separator 12 has a shape of a funnel. The separator 12 is interposed between the outlet pipe 9 and the outlet duct 15 which releases the fluid. The separator 12 comprises perforations arranged to allow the fluid to pass through to the outlet duct 15 but not the cleaning balls 20.

Preferably, the perforations are in the form of rectangular slots 32 having a length direction inclined in a particular direction, for example anti-clockwise, as viewed in the fluid flow direction. Detailed views of the separator 12 according to this embodiment and the inclined slots 32 are shown in Figures 5 and 6, respectively. The separator 12 is connected to the recirculating means for transferring the cleaning balls 20 from the outlet pipe 9 to the inlet pipe 5.

In this embodiment, the recirculating means comprises a housing 21 for collecting the cleaning balls 20. The housing 21 has an apertured partition 28 dividing the interior of the housing 21 into an first compartment 19 and a second

compartment 27 on opposite sides of the partition 28. The partition 28 permits the fluid, but not the cleaning balls 20, to pass through so that the cleaning balls 20 accumulate within the first compartment 19. The housing 21 may further include a cover 18 for covering the first compartment 19 and which is removable therefrom in order to add or remove the cleaning balls 20.

The recirculating means further comprises a fluid return pipe 16 and a ball return pipe 17. The fluid return pipe 16 is used to connect the housing 21 to the outlet duct 15 for transferring the fluid (not the cleaning balls 20) from the housing 21 to the outlet duct 15. The fluid return pipe 16 has an entrance 30 on the second compartment 27 of the housing 21 and an exit 14 on the outlet duct 15. The ball return pipe 17 is used to connect the separator 12 to the housing 21 for transferring the cleaning balls 20 from the outlet pipe 9 to the housing 21. The ball return pipe 17 has an entrance 13 on the separator and an exit 31 on the first compartment 19 of the housing 21. The entrance open mouth 13 of the ball return pipe 17 is formed in the direction against the fluid flow W3 of the outlet pipe 9 such that the pressure at the entrance 13 of the ball return pipe 17 is higher than that at the exit 14 of the fluid return pipe 16. The ball return pipe 17 may include a hand valve HV2 which is always open except when replacing or adding the cleaning balls 20.

The recirculating means also comprises a ball supply pipe 24 and a fluid supply

pipe 23. The ball supply pipe 24 is used to connect the housing 21 to the inlet pipe 5 for supplying the cleaning balls 20 back to the inlet pipe 5 from the housing 21. The ball supply pipe 24 has an entrance 26 on the first compartment 19 of the housing 21 and an exit 3 on the inlet pipe 5. The ball supply pipe 24 may include a hand valve HV1 which is always open except when changing the cleaning balls 20. The fluid supply pipe 23 is used to connect the inlet pipe 5 to the housing 21 for supplying the fluid from the inlet pipe 5 to the housing 21. The fluid supply pipe 23 has an entrance 2 on the inlet pipe 5 and an exit 22 on the first compartment 19 of the housing 21. The entrance open mouth 2 of the fluid supply pipe 23 is formed in the direction against the fluid flow W1 of the inlet pipe 5 such that the pressure at the entrance 2 of the fluid supply pipe 23 is higher than that at the exit 3 of the ball supply pipe 24.

The housing 21 further comprises two valves SV1 and SV2 disposed along the fluid supply pipe 23 and the fluid return pipe 16 for controlling the cleaning balls 20 flow from the downstream side of the condenser tubing 8 to the upstream side of the condenser tubing 8 via the housing 21. The first valve SV1 is operative to control the cleaning balls 20 flow from the housing 21 to the inlet pipe 5 and the second valve SV2 is operative to control the cleaning balls 20 flow from the separator 12 to the housing 21.

The housing 21 also comprises two check valves or one-way valves, CV1 and

CV2 disposed along the ball supply pipe 24 and the ball return pipe 17. The first check valve CV1 only permits the fluid and the cleaning balls 20 flow in the direction from the housing 21 to the inlet pipe 5, and not vice versa. The second check valve CV2 only permits the fluid and the cleaning balls 20 flow in the direction from the separator 12 to the housing 21, and not vice versa.

The cleaning system may further comprise rotation means arranged at the inlet pipe 5 and outlet pipe 9 and in this embodiment propellers are used.

A first propeller 4 is placed at the inlet pipe 5 and before the tubing 8 to rotate the cleaning balls 20 so that the cleaning balls 20 enter the tubing 8 in a random pattern, as indicated by reference numeral 6. A second propeller 10 is placed at the outlet pipe 9 and before the separator 12 so that the fluid and the cleaning balls 20 are rotated to let the cleaning balls 20 collide with each other at the mouth 11 of the separator 12.

Having described the various components of the cleaning system, an operation of the system will now be described with reference to Figures 1, 2, 3 and 4.

We assume an initial position, which is illustrated in Figure 1, whereby the valves SV1 and SV2 are closed and the cleaning balls 20 are accumulated within the first compartment 19 of the housing 21. There is no flowing of fluid in the ball

supply pipe 24 and the ball return pipe 17 because of the pressure at the exit 3 of the ball supply pipe 24 is higher than that at the entrance 13 of the ball return pipe 17 and the function of the two check valves CV1 and CV2.

When the condenser 7 is operating, the cooling fluid is going through the inlet pipe 5. According to a principle of fluid mechanics, the static pressure at the entrance 2 of the fluid supply pipe 23 would be higher than that at the exit 3 of the ball supply pipe 24 because of the entrance open mouth 2 of the fluid supply pipe 23 is formed in the direction against the fluid flow W1of the inlet pipe 5. This difference in pressure creates a suction force to draw or suck the fluid from the inlet pipe 5 into the housing 21 via the fluid supply pipe 23 and to draw or suck the fluid (and the cleaning balls 20) from the housing 21 into the inlet pipe 5 via the ball return pipe 24.

To allow the cleaning balls 20 to be drawn out from the housing 21 to the inlet pipe 5, the first valve SV1 is opened with the second valve SV2 is closed, so that the fluid drawn from the inlet pipe 5 to the housing 21 and the cleaning balls 20 are then sucked out from the housing 21 and into the inlet pipe 5 for circulating to the tubing 8 to clean the internal walls of the tubing 8. This is the condition illustrated in Figure 2.

The operation of transferring the cleaning balls 20 from the housing 21 to the

upstream side of the tubing 8, which based on the difference in pressure of the entrance 2 of the fluid supply pipe 23 and the exit 3 of the ball supply pipe 24 is ball supply operation.

After all the cleaning balls 20 are drawn into the inlet pipe 5, both valves SV1 and SV2 can then be closed. The ball supply operation is stopped when the first valve SV1 is closed.

The first propeller 4, at the time when the first valve SV1 is opened, is also activated to force the fluid flow W2 to rotate and also the cleaning balls 20 and as a result the cleaning balls 20 enter the tubing 8 randomly. After the cleaning process, the second propeller 10 again rotates the cleaning balls 20 so that the cleaning balls 20 collide with each other and the dirt particles, which were removed by the cleaning balls from tubing 8 and are now attached to the balls, are "rubbed" off. The dirt particles would then be carried by the fluid flow W3 for discharge though the outlet duct 15. It should be noted that the direction of rotation of the second propeller 10 and thus the cleaning balls 20 is preferably in the opposite direction when compared to the inclined slots 32 of the separator 12. For example, if the length direction of the inclined slots 32 is anti-clockwise, then the rotation of the cleaning balls 20 by the propeller 10 should, preferably, be clockwise. This would increase the collision of the balls with each other.

After the rotation, the cleaning balls 20 accumulate at the mouth 11 of the separator 12, as illustrated in Figure 3.

According to a principle of fluid mechanics, the static pressure at the entrance 13 of the ball return pipe 17 would be higher than that at the exit 14 of the fluid return pipe 16 because of the entrance open mouth 13 of the ball return pipe 17 is formed in the direction against the fluid flow W3 of the outlet pipe 9. This difference in pressure creates a suction force to draw or suck the fluid (and the cleaning balls 20) from the separator 12 and into the housing 21 via the ball return pipe 17 and to draw or suck the fluid (not the cleaning balls 20, because of the apertured partition 28 of the housing 21) from the housing 21 to the outlet duct 15 via the fluid return pipe 16.

To return the cleaning balls 20 to the housing 21, the second valve SV2 is opened (and the first valve SV1 closed), so that the cleaning balls 20 are sucked from the separator 12 to the housing 21 and the fluid (not the cleaning balls, because of the apertured partition 28 of the housing 21) drawn from the housing 21 to the outlet duct 15. This is the condition illustrated in Figure 4.

The operation of transferring the cleaning balls 20 from the downstream side of the tubing 8 to the housing 21, which based on the difference in pressure of the entrance 13 of the ball return pipe 17 and the exit 14 of the fluid return pipe 16 is

ball return operation.

Finally, all the cleaning balls 20 arrive back at the first compartment 19 of the housing 21 and accumulated there when both valves SV1 and SV2 are closed, as illustrated in Figure 1. The ball return operation is stopped when the second valve is closed.

When a need arises, when the cleaning balls 20 need to be replaced, the hand valves HV1 and HV2 are closed and the cover 18 is opened, so that the cleaning balls 20 can be replaced.

From the described embodiment, it can be observed that the operation of the whole cleaning system can easily be controlled via the two valves SV1 and SV2, which can be manually operated or means provided to operate them automatically. In addition, the system does not waste the cooling fluid which can easily be recirculated together with the cleaning balls 20.

While the invention has been described with respect to one preferred embodiment, it will be appreciated that this is set forth merely for purposes of example, and that many variations, modifications and applications of the invention may be made.

Claims

1. A system for cleaning tubing used for conducting a fluid therethrough, the tubing being connected to an inlet pipe and an outlet pipe, the system comprising

a plurality of cleaning elements for circulating with the fluid through the tubing;

a separator disposed at the outlet pipe and arranged to separate the cleaning elements from the fluid; and

recirculating means arranged to selectively transfer the plurality of cleaning elements from the outlet pipe to the inlet pipe, wherein the recirculating means comprises

a housing arranged to collect the cleaning elements, the housing having a first and second compartment separated by an apertured partition, the partition arranged to allow the fluid to pass through to the second compartment but not the cleaning elements;

a ball supply pipe having an entrance coupled to a first opening on the first compartment of the housing and an exit coupled to a first opening on the inlet pipe;

a fluid supply pipe having an entrance coupled to a second opening on the inlet pipe and an exit coupled to a second opening on the first compartment of the housing;

the entrance open mouth of the fluid supply pipe is formed in the direction against the fluid flow of the inlet pipe such that the pressure at the entrance of the fluid supply pipe is higher than that at the exit of the ball supply pipe;

a fluid return pipe having an entrance coupled to an opening on the second compartment of the housing and an exit coupled to an opening on the outlet pipe;

a ball return pipe having an entrance coupled to an opening on the separator and an exit coupled to a third opening on the first compartment of the housing;

the entrance open mouth of the ball return pipe is formed in the direction against the fluid flow of the outlet pipe such that the pressure at the entrance of the ball return pipe is higher than that at the exit of the fluid return pipe;

a ball return operation is an operation for transferring the plurality of cleaning elements from the separator to the housing, which based on the difference in pressure of the entrance of the ball return pipe and the exit of the fluid return pipe; and

a ball supply operation is an operation for transferring the plurality of cleaning elements from the housing to the inlet pipe, which based on the difference in pressure of the entrance of the fluid supply pipe and the exit of the ball supply pipe.

2. A cleaning system according to claim 1, wherein the recirculating means further comprises a first valve disposed along the fluid supply pipe, a second valve disposed along the fluid return pipe, a first one-way valve disposed along the ball supply pipe, and a second one-way valve disposed along the ball return pipe; the first valve being operative to transfer the cleaning elements from the housing to the inlet pipe and the second valve being operative to transfer the cleaning elements from the separator to the housing.

3. A cleaning system according to claim 1 or claim 2, wherein the recirculating means further comprising a third valve disposed along the ball return pipe.

4. A cleaning system according to any one of the preceding claims, wherein the separator is in a shape of a funnel.

5. A cleaning system according to claim 4, wherein the separator comprises perforations which allow the fluid to flow through but not the cleaning elements.

6. A cleaning system according to claim 5, wherein the perforations are in

the form of rectangular slots each having a length direction.

7. A cleaning system according to claim 6, wherein the length directions of the rectangular slots are not parallel to the centre axis of the funnel.

8. A cleaning system according to any one of the preceding claims, further comprising means to rotate the fluid and the cleaning elements at the inlet pipe before the tubing.

9. A cleaning system according to any one of the preceding claims, further comprising means to rotate the fluid and the cleaning elements at the outlet pipe before the separator.

10. A cleaning system according to claim 6 or claim 7, and dependent on claim 9, wherein the direction of the rotational means is opposite to the length direction of the rectangular slots.

11. A cleaning system according to claim 1, wherein the ball return operation is depending the pressure at the entrance of the ball return pipe higher than that at the exit of the fluid return pipe for transferring the plurality of cleaning elements from the separator to the first compartment of the housing; The difference in pressure creates a suction force to draw or

suck the fluid and the cleaning elements from the separator and into the housing via the ball return pipe and to draw or suck the fluid, not the cleaning elements from the housing to the outlet pipe via the fluid return pipe.

12. A cleaning system according to claim 1, wherein the ball supply operation is depending the pressure at the entrance of the fluid supply pipe higher than that at the exit of the ball supply pipe for transferring the plurality of cleaning elements from the first compartment of the housing to the inlet pipe. The difference in pressure creates a suction force to draw or suck the fluid from the inlet pipe and into the housing via the fluid supply pipe and to draw or suck the fluid and the cleaning elements from the housing to the inlet pipe via the ball supply pipe.

ABSTRACT

A Cleaning System

A cleaning system for cleaning tubing using cleaning balls 20 circulated with the fluid through tubing 8. The system includes a separator 12 having a perforated funnel, which permits the fluid, but not the balls 20, to pass through. A housing 21 having an apertured partition 28 is used to divide the housing 21 into an first compartment 19 and a second compartment 27. An entrance 2 of a fluid supply pipe 23 and an exit 3 of a ball supply pipe 24 are formed for creating a difference in pressure to create a suction force to recirculate the balls 20 from the housing 21 via the ball supply pipe 24, back to the tubing 8 for cleaning the walls of the tubing 8. An entrance 13 of a ball return pipe 17 and an exit 14 of a fluid return pipe 16 are formed for creating a difference in pressure to create a suction force to recirculate the balls 20 from the separator 12 via the ball return pipe 17, into the housing 21.

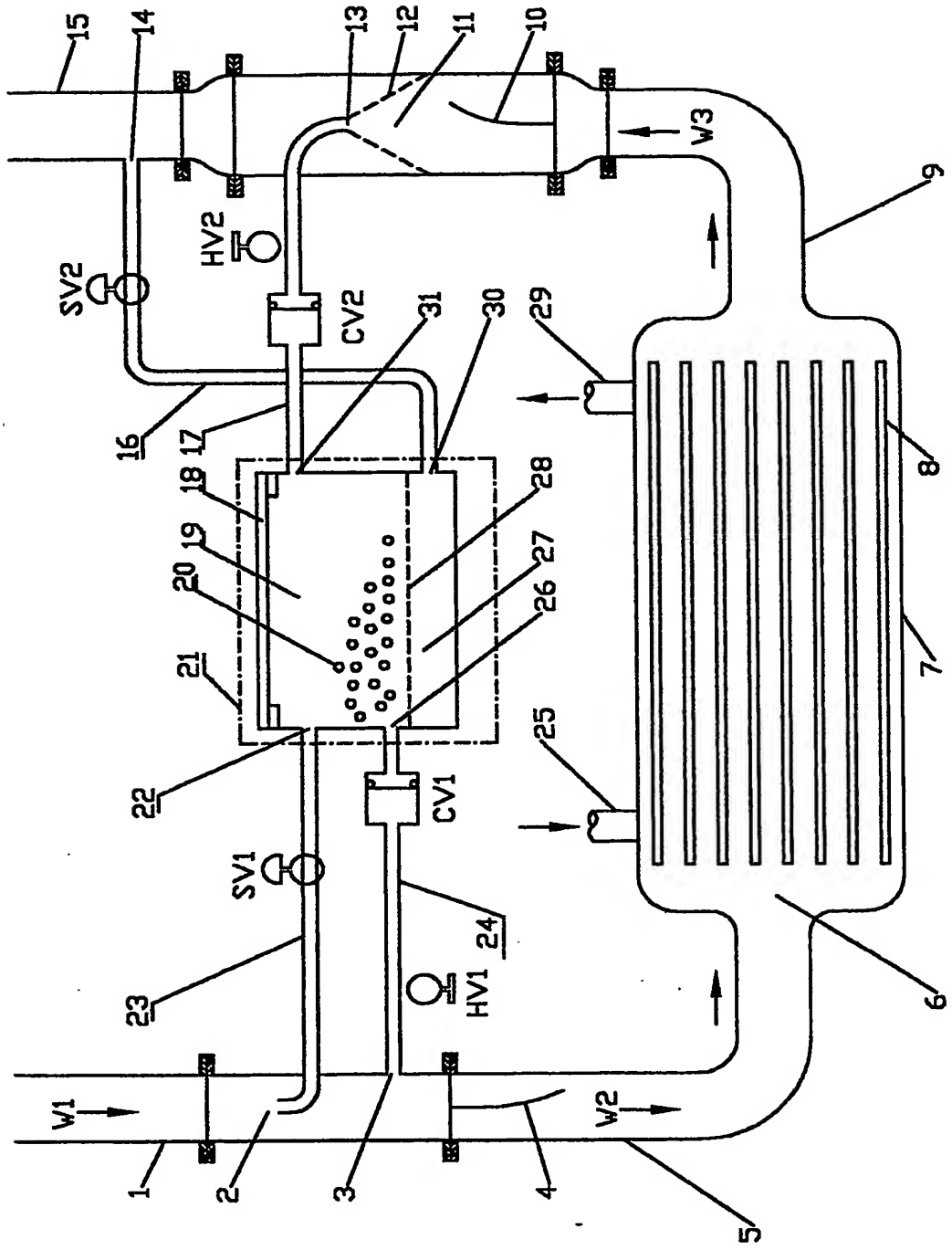

Figure 1 Balls initial process

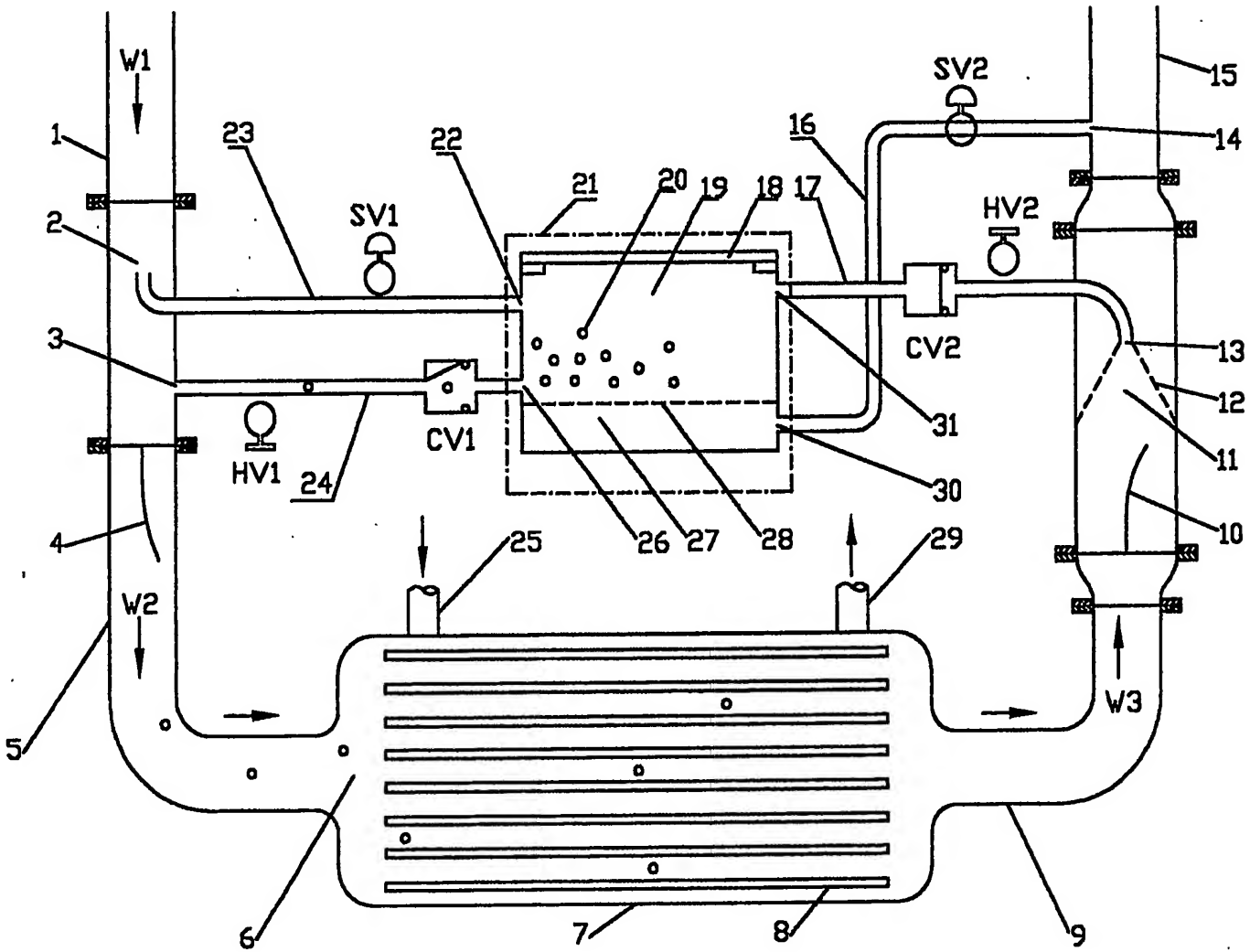

Figure 2 Balls cleaning process

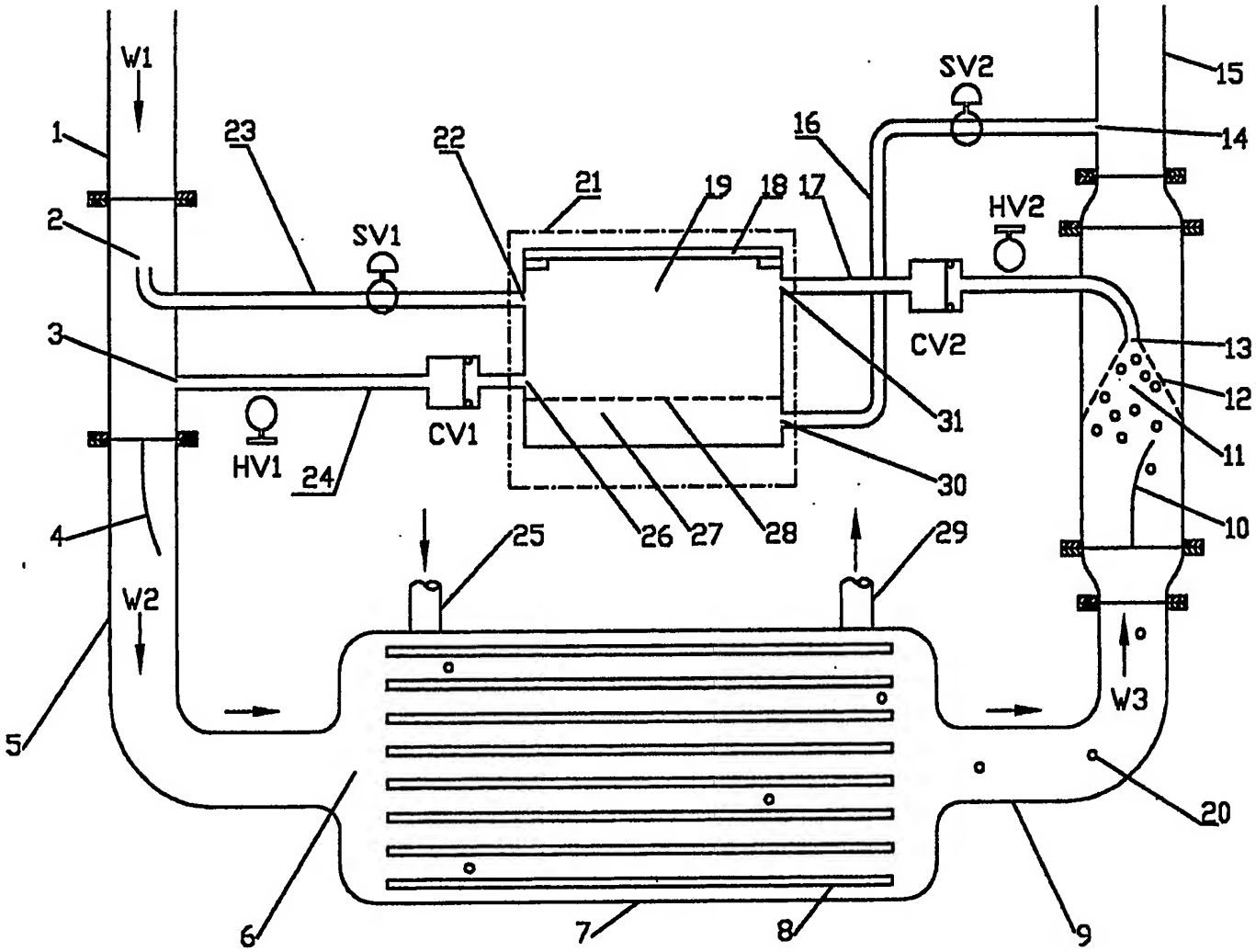

Figure 3 Balls collision process

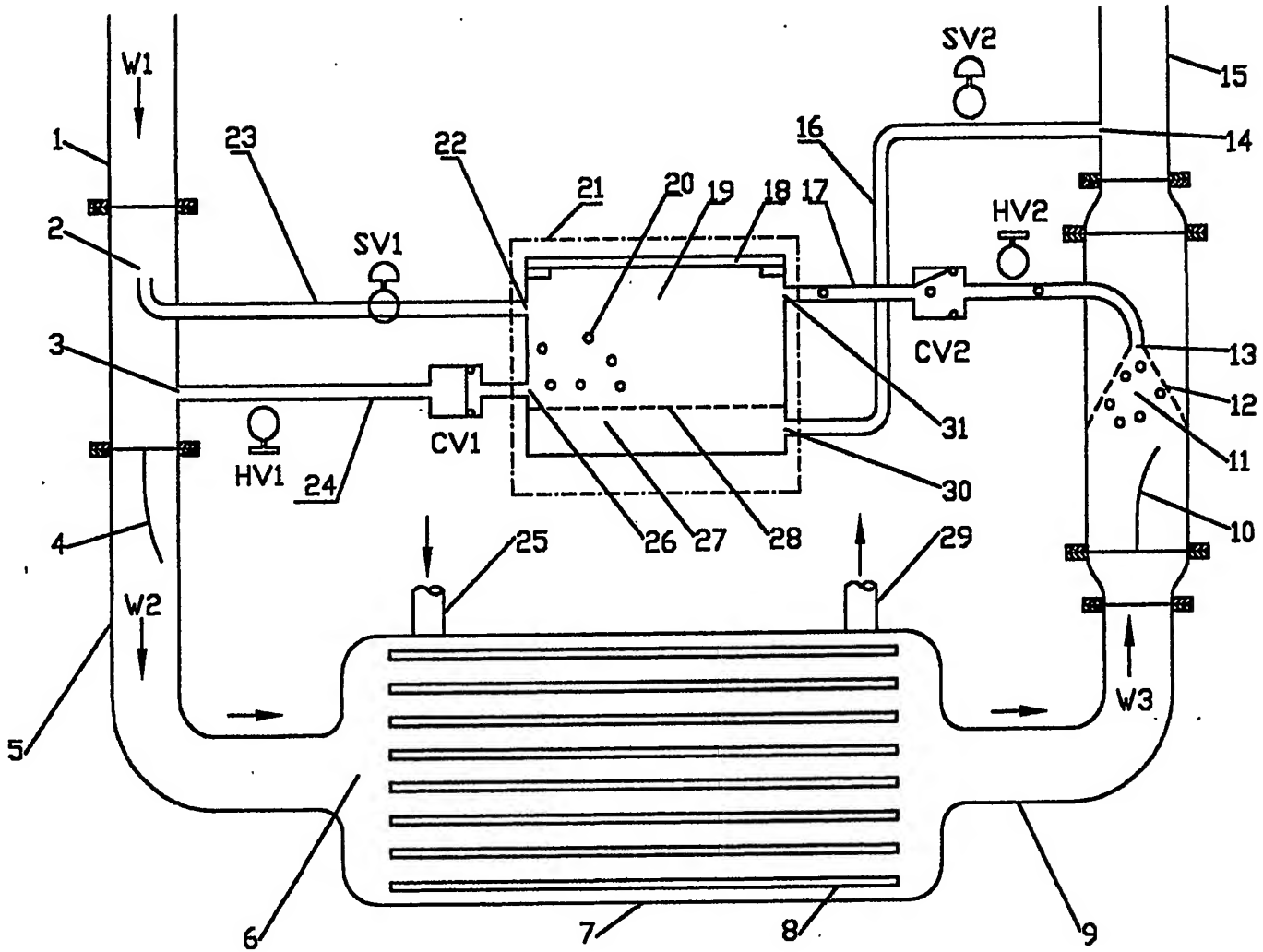

Figure 4 Balls return process

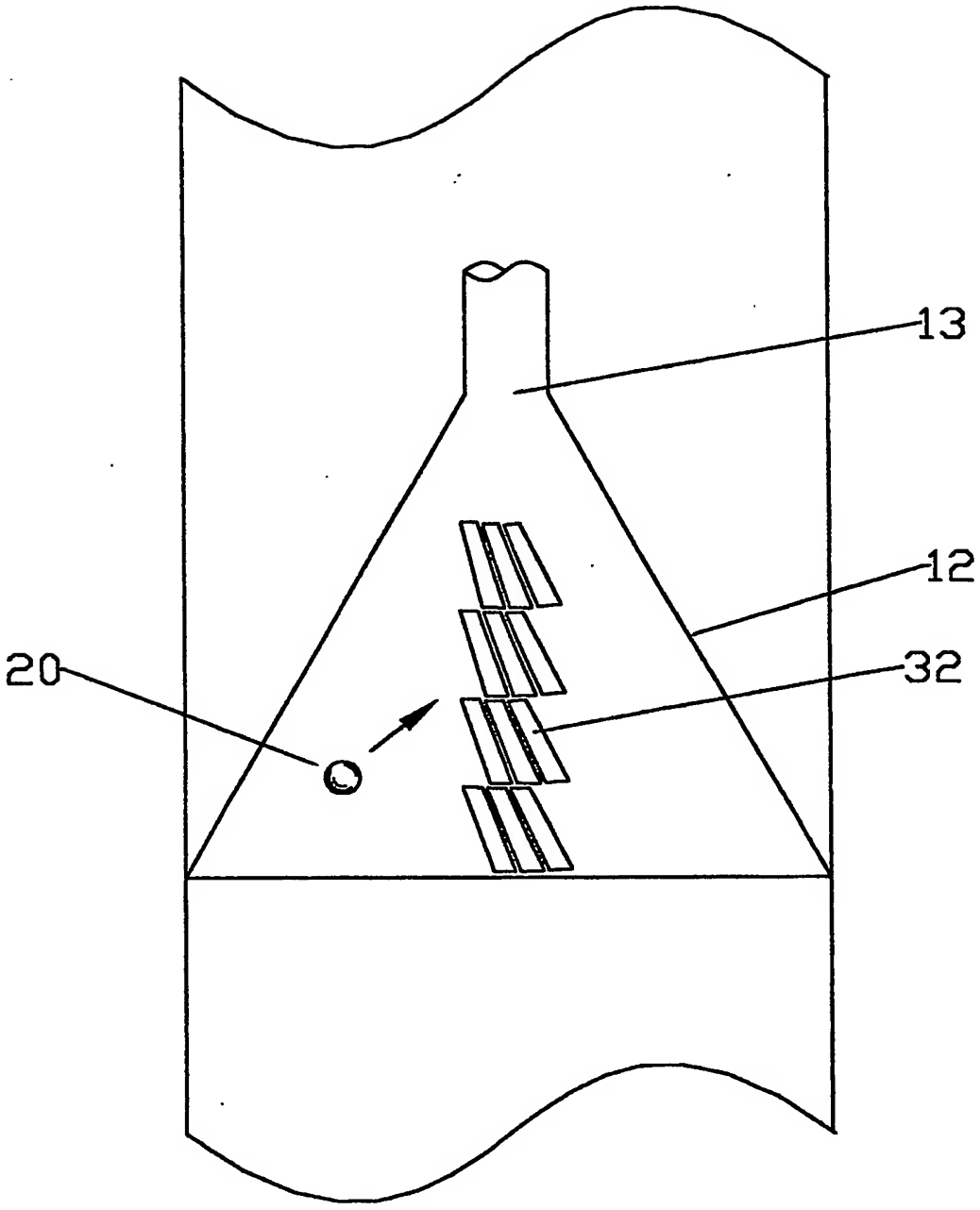

Figure 5 Separator detail

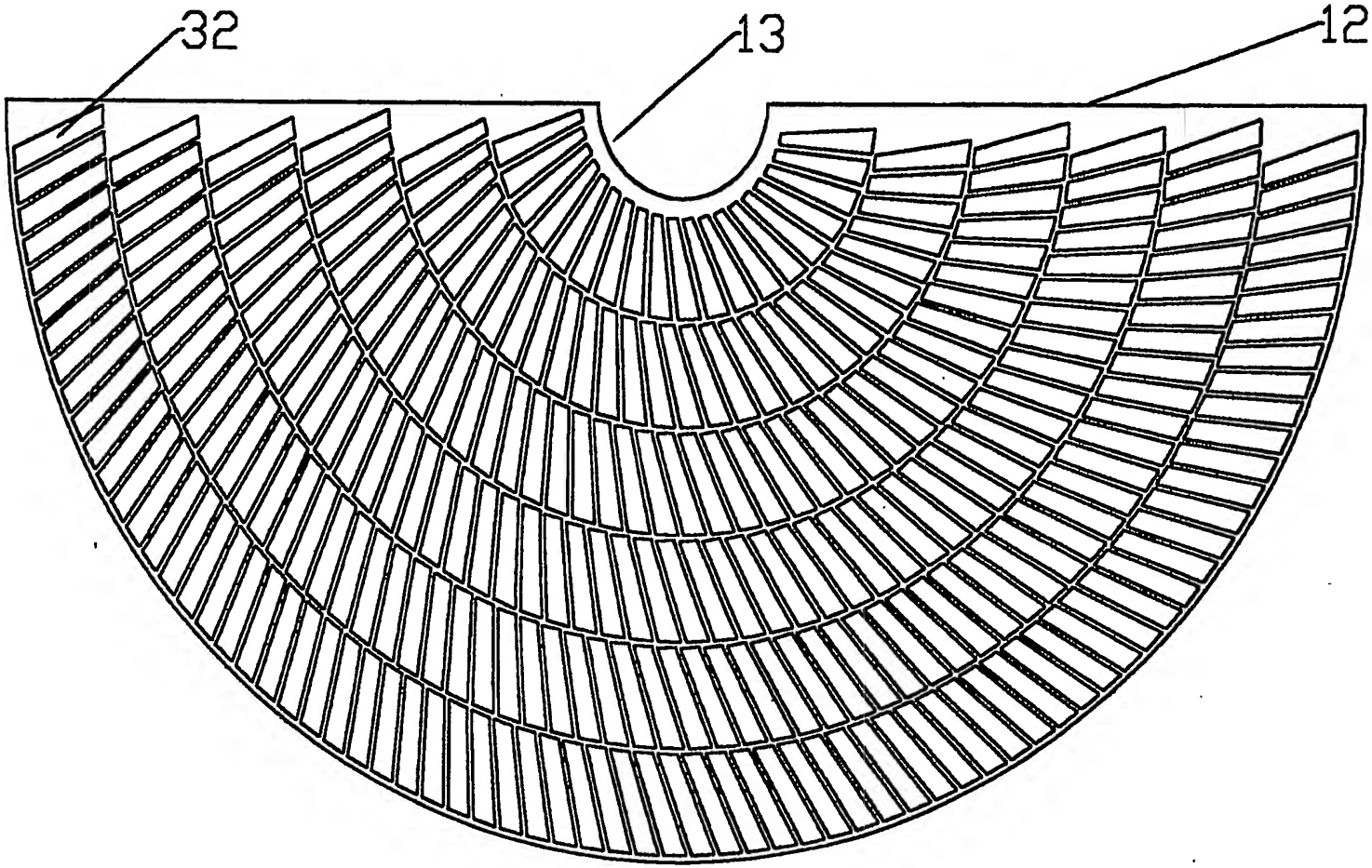

Figure 6 Separator spread view